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(54) **Surround sound channel encoding and decoding**

(57) Surround sound decoding apparatus includes a left combined input, a left signal output, a right signal output, a center signal output and a surround output. A plurality of algebraic signal combiners intercouple the left combined input, the right combined input, the left, right, center and surround outputs are constructed and arranged to provide a left signal on the left output representative of a left channel signal component in the signal on the left combined signal input, a right signal on the right output representative of a right channel component in a signal on the right combined input. A center signal on the center signal output representative of center signal components of signals on the left combined signal input and the right combined signal input, and a surround signal on the surround output representative of a surround components in the signals on the left combined input and the right combined input. Surround sound encoding apparatus includes a source of left, right, center, left surround, right surround and low frequency effect signals. A left combiner has a left input for receiving the left signal, a left surround input for receiving the left surround signal, a left low frequency effect input for receiving substantially 0.707 of the low frequency effect signal, and a left center input for receiving substantially 0.707 of the center signal and an output for providing a left transmitted signal representative of the cumulative combination of the signals on these inputs. The surround sound encoding apparatus also includes a right combiner having a right input for receiving the right signal, a right surround input for receiving the right surround signal, a right low frequency effect input for receiving substantially 0.707 low frequency effect signal, and a right center input for receiving substantially 0.707 of the center signal and an output for providing a right transmitted signal representative of the cumulative combination of the signals on the inputs of the right combiner.

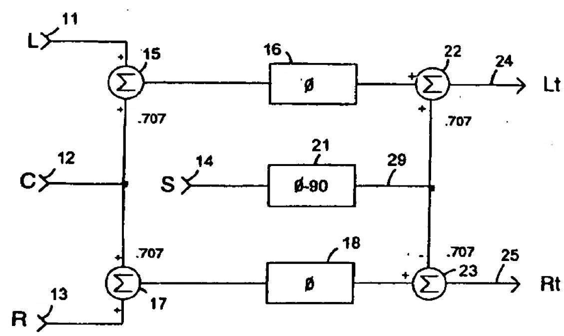

FIG. 1

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With reference now to the drawings and more particularly FIG. 1, there is shown the logical arrangement of a generalized standard matrix encoder left, center, right and surround input terminals 11, 12, 13 and 14 receive left, center, right and surround signals, respectively. Left-center adder 15 combines the signals on left and center input terminals 11 and 12 to provide a left-center signal to left center phase shift network 16. Right-center summer 17 combines the signals on center and right terminals 12 and 13 to provide a right-center signal to right-center phase shift network 18. Quadrature phase shifter 21 receives the surround signal on terminal 14 to provide a quadrature phase-shifted surround signal that is combined with the left-center phase-shifted signal provided by left-center phase shifter 16 to left output adder 22 to provide the left transmitted signal LT and with the right-center phase-shifted signal provided by right-center phase shifter 18 to right output adder 23 to provide the right-transmitted signal RT.

The surround channel and center channel signals are defined as equal amplitude out-of-phase and in-phase signals, respectively. Encoding a left and center channel signal simultaneously produces only the center channel output at the output of right output adder 23, and the left channel signal plus the center channel signal at the output of left adder 22. Thus, the left and center channel signals cannot be accurately retrieved without first normalizing the relative time-average magnitudes of the left and right transmitted signals LT and RT such that LT is equal to RT at the input terminals of the input amplitude normalization circuitry shown in FIG. 2.

Referring to FIG. 2, the left and right transmitted signals LT and RT from left and right output adders 22 and 23, respectively, on terminals 24 and 25, respectively, are multiplied by right and left magnitude signals [R]/Y and [L] /Y, respectively, on input terminals 26 and 27, respectively, of sum and difference multiplier 31 and 32, respectively. The outputs of left and right multipliers 31 and 32 are cumulatively combined in adder 33 and differentially combined in subtractor 34 to provide on terminals 35 and 36 sum and difference levels, respectively.

One method of normalizing the relative magnitudes of LT and RT at the decoder input terminals involves deriving the time-averaged magnitude of LT, RT, and the time-averaged magnitude of whichever of the two is greater when [LT] ≠ [RT] (herein referred to as Y) . When the two magnitudes are equal, Y is either the time-averaged magnitude of [LT] or [RT]. Expressing these magnitudes in terms of Y produces two usable coefficients:

$$A1 = [LT]/Y$$

and

$$A2 = [RT]/Y.$$

For all LT dominant conditions, the coefficient A1 has a value of one, and the coefficient A2 is the ratio of the magnitudes of RT to LT. The opposite is true for all RT dominant input signal conditions. The domain of each of the two coefficients is from 0 to 1 inclusive. Multiplying LT by [RT]/Y and RT by [LT]/Y produces equal magnitude signals at the output of each of multipliers 31 and 32. If the normalization function is the result of a broadband measurement of the spectrum at LT and RT, then summing the modified signal will not, in all cases, produce the encoded center channel or surround channel signal because the sum signal or difference signal may yet contain information for reproduction by the left (or right) channel signal.

For example, consider encoding the center and left channel signals as two sine waves of arbitrary frequency. If the left channel signal L is 5 kHz, and the center channel signal is a 1 kHz signal, each with a unit amplitude of 1 at the encoder output terminals, since the left channel signal is the greater of the left and right channel signals, the coefficient A1 has a value of 1, and the coefficient of A2 has a value 0.707. Thus, the output of sum multiplier 31 is 0.707 (5 kHz sine wave + 1 kHz sine wave) and the output of right multiplier 32 is 1 (1 kHz sine wave). The sum and the difference signals obtained in this example both contain .3535 (5 kHz sine wave), which originated as a left channel signal and not as a center or surround channel signal.

Now compare the results of this example with those obtained when the two signals are of the same frequency and phase. In this example, A1 has a value of 1, and the coefficient A2 has a value of 0.5. The resulting outputs of left multiplier 31 and right multiplier 32 are equal, with a unit amplitude of 1. In this example, the sum of the signals and the absence of a difference signal are expected conditions and accurately represent the information in the signals originally encoded.

It has been discovered that the distinction between these and similar examples resides in the indication (or absence) of a difference signal. Stated in general terms, the difference signal obtained when the spectrum is sum signal and left (or right) channel dominant, contains some of the left (or right) channel signal. Similarly, the sum signal obtained when the spectrum is difference signal dominant and left (or right) channel dominant contains some of the left (or right) channel signal. The invention takes advantage of this property to remove the undesired signal from the resulting sum and difference signals furnished by sum and difference summers 33 and 34.

Referring to FIGS. 3A and 3B, there is shown the logical arrangement of apparatus for generating a difference signal output for sum signal dominance and a sum signal output for difference signal dominance.

It is convenient to establish the condition of sum or difference signal dominance by deriving the time-averaged magnitude of each of these signal quantities, and the time-averaged magnitude of whichever of the two is

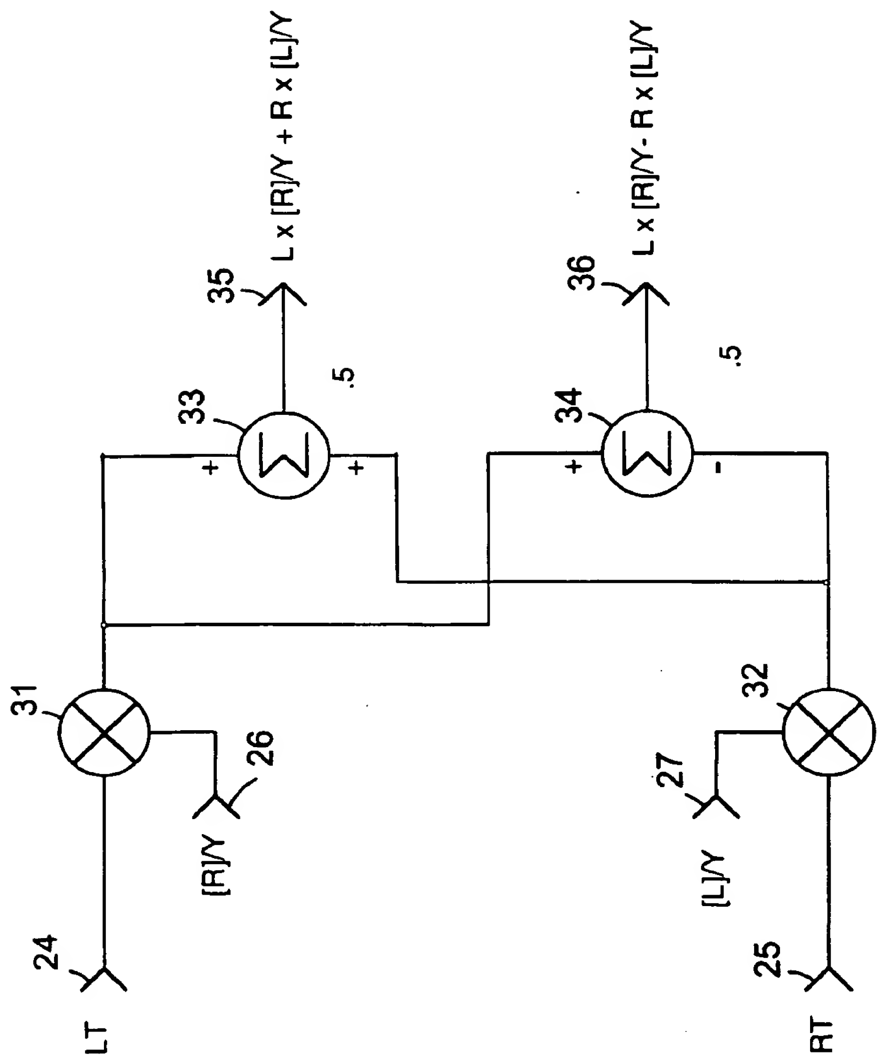

FIG. 2